

## Structural and dielectric properties of $\text{KBa}_5\text{TiNb}_9\text{O}_{30}$ ferroelectrics

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**Abstract** : Potassium barium titanium niobate (hereafter PBTN) having composition  $\text{KBa}_5\text{TiNb}_9\text{O}_{30}$  has been synthesized by high temperature solid-state reaction technique. Room temperature X-ray diffraction (XRD) studies of the compound show that it has a tetragonal structure with lattice parameters  $a = b = 12.43 \text{ \AA}$  and  $c = 4.10 \text{ \AA}$ . Measurement of dielectric constant from liquid nitrogen temperature to  $400^\circ\text{C}$  suggests that the material is ferroelectric at room temperature and transforms into a paraelectric phase at around  $290^\circ\text{C}$ .

**Keywords** : Tetragonal structure, dielectric constant, ferroelectric material

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Potassium barium titanium niobate ( $\text{KBa}_5\text{TiNb}_9\text{O}_{30}$ ) belongs to a ferroelectric oxide family of tungsten-bronze (TB) structure [1] of general formula  $\text{AB}_5\text{TiNb}_9\text{O}_{30}$  ( $A = \text{Na, K}$  and  $B = \text{Sr, Ba}$ ). The tungsten-bronze (TB) structure consists of a complex array of distorted  $\text{BO}_6$  octahedra sharing corners in such a way that the different types of interstices ( $A_1, A_2, B_1, B_2$  and  $C$ ) are available for cation substitution [2]. The polar axis of most of the members of TB family is normally  $c$ -axis. A wide variety and range of compounds of tungsten-bronze (TB) type has been studied. Some niobates with TB structure such as barium sodium niobate and potassium lanthanum niobates [3] are quite attractive and interesting owing to their wide industrial applications. Studies of structural and dielectric properties of some ferroelectric oxides of TB structure [4,5] have been reported. The electrical conductivity measurements of a few compounds [6] also confirm the occurrence of offset near the transition temperature.

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A literature survey reveals that even though the compound has been suggested to be ferroelectric, no systematic X-ray and detailed dielectric studies have yet been reported. We, therefore, present in this paper preliminary structural and detailed electrical (dielectric constant ( $\epsilon$ ) and loss ( $\tan \delta$ )) properties of the PBTN compound.

The polycrystalline samples of PBTN were prepared by a standard high-temperature solid-state reaction technique from the raw materials :  $\text{TiO}_2$  (99 % s.d. fine chem Pvt. Ltd.),  $\text{Nb}_2\text{O}_5$  (99.9 % SMP),  $\text{K}_2\text{CO}_3$  (99.9 % SM Chemicals) and  $\text{BaCO}_3$  (M/s Ultra Pure LOBA CHEMIE) in a suitable proportion. These oxides and carbonates were thoroughly mixed in an agate-mortar in alcohol for 10 h and dried. The dried powders were calcined in a crucible at  $1050^\circ\text{C}$  for 25 h. The process of calcination and mixing was repeated till the final homogeneous powder of PBTN was obtained. The formation and quality of the compound were checked with X-ray diffraction technique. Some of cylindrical pellets (of diameter 10.3 mm and thickness 2.3 mm) were made under the isostatic pressure ( $6 \times 10^7 \text{ Kg/cm}^2$ ) using a hydraulic press. The pellets were then sintered in air atmosphere at  $1100^\circ\text{C}$  for 10 h. After polishing and grinding, both the flat surfaces of some pellets were electroded with air drying silver paints for electrical measurements.

The X-ray diffractograms of the PBTN pellet samples were taken with  $\text{CuK}_\alpha$  radiation ( $\lambda = 1.5418 \text{ \AA}$ ) in a wide  $2\theta$  range ( $20^\circ \leq 2\theta \leq 70^\circ$ ) with Philips powder diffractometer (PW 1710 Holland).

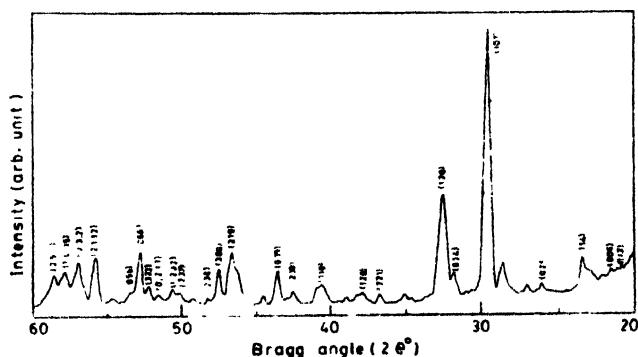


Figure 1. X-ray diffractogram of PBTN pellet sample.

The dielectric permittivity ( $\epsilon'$ ) and loss ( $\tan \delta$ ) were obtained on the sintered and electroded pellet samples as functions of frequencies (500 Hz to 10 KHz) and temperature (liquid nitrogen to  $400^\circ\text{C}$ ) using G R 1620 capacitance measuring assembly. The reliability of the data was checked by repeating the experiments with different instruments (LCR-High tester, Hioki 5530, Japan) in the same physical conditions.

Following the data given in Landolt-Bornstein tables [7], all the prominent peaks in Figure 1 were indexed using tetragonal unit cells. A good agreement between the observed and calculated  $d$ -values suggests that the choice of unit cells is correct and the corresponding lattice parameters are  $a = b = 12.43 \text{ \AA}$  and  $c = 4.10 \text{ \AA}$ .

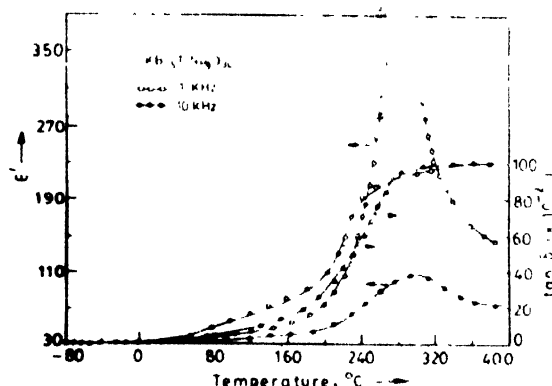


Figure 2. Variation of dielectric permittivity ( $\epsilon'$ ) and dielectric loss ( $\tan \delta$ ) with temperature at two frequencies 1 kHz and 10 kHz

Figure 2 shows that the variation of dielectric permittivity ( $\epsilon'$ ) and dielectric loss ( $\tan \delta$ ) with temperature at two frequencies 1 kHz and 10 kHz. It is evident from this figure that the dielectric permittivity increases gradually above room temperature and becomes maximum around  $290^\circ\text{C}$ . The dielectric loss on the other hand increases up to about  $290^\circ\text{C}$  and then levels off. The reason for levelling off may be due to increased ac conductivity of the sample. The peak in the dielectric permittivity ( $\epsilon'$ ) around  $290^\circ\text{C}$  is indicative of ferroelectric phase transition.

It is thus concluded that PBTN is tetragonal at room temperature and it may possess ferroelectric property with a ferroelectric phase transition temperature of  $290^\circ\text{C}$  which is quite high as compared to other members of the family.

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